

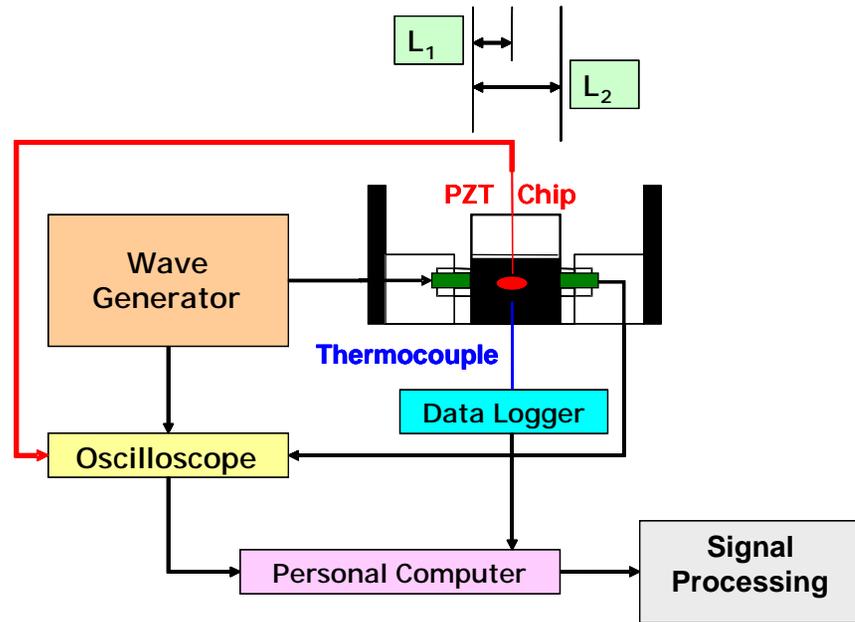
Prognostics For Structural Health Monitoring: A Multidisciplinary Approach

Contributors from
Mechanical Engineering
Electrical and Computer Engineering
Materials Science and Engineering
Civil and Environmental Engineering

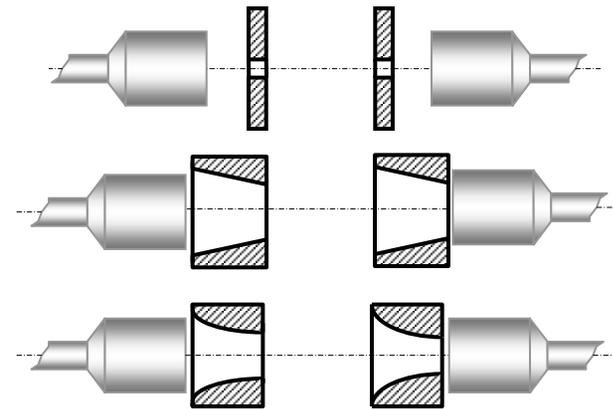
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Embedded, Airborne and Conventional Piezoelectric Sensors



Embedded Sensors for Process Monitoring



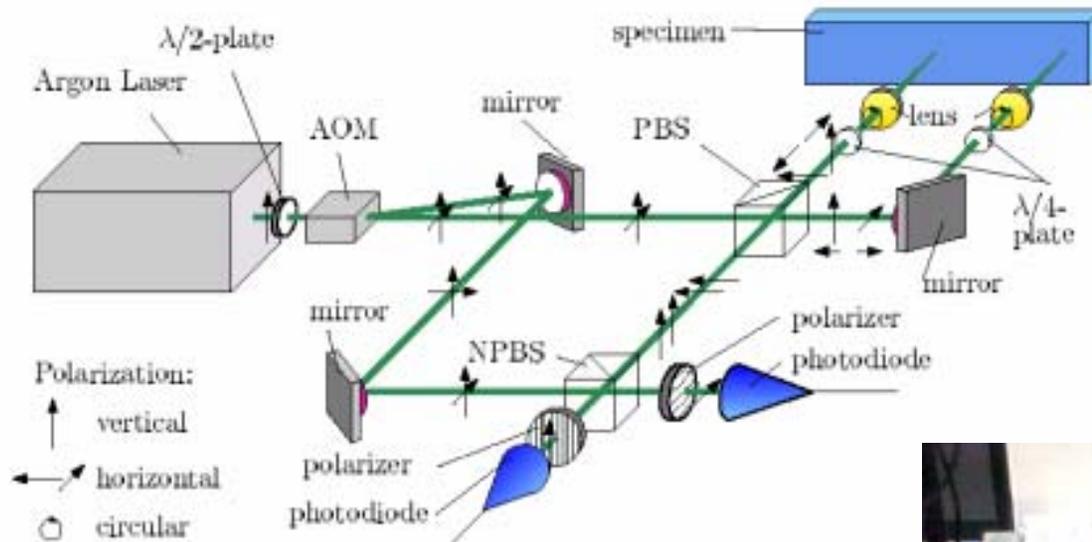
Airborne Ultrasound
For Non-Contact Monitoring
And Imaging



Conventional Immersion
And Contact Transducers



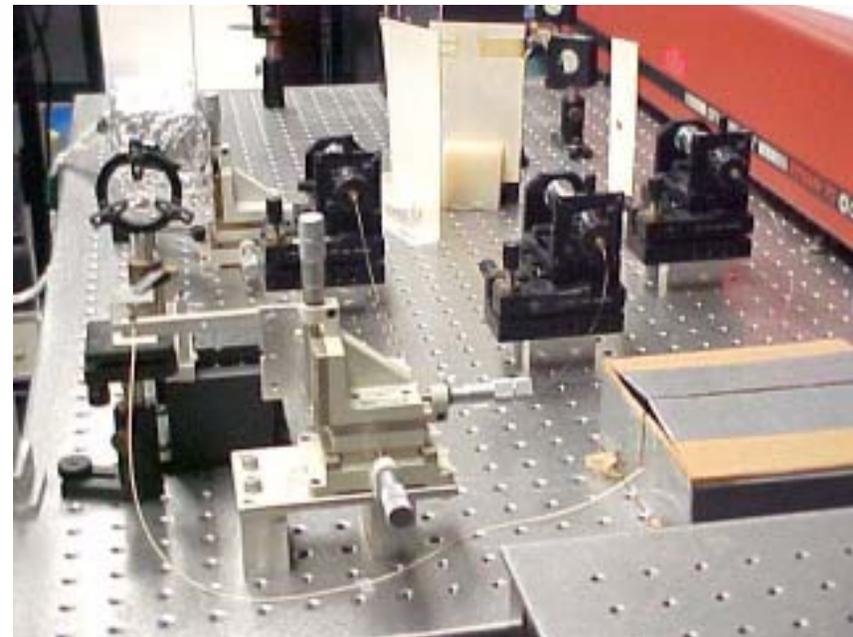
Laser System for Ultrasound Generation and Reception



Pulse laser to generate ultrasonic wave

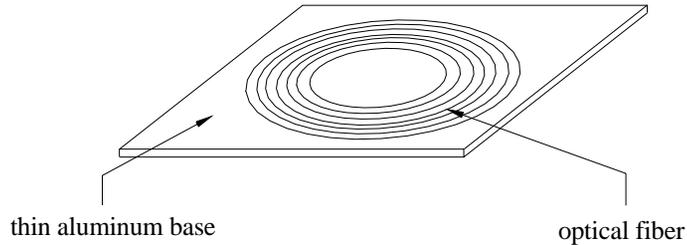
Fiber-optic delivery

Dual probe laser interferometer for in-plane and out-of-plane detection



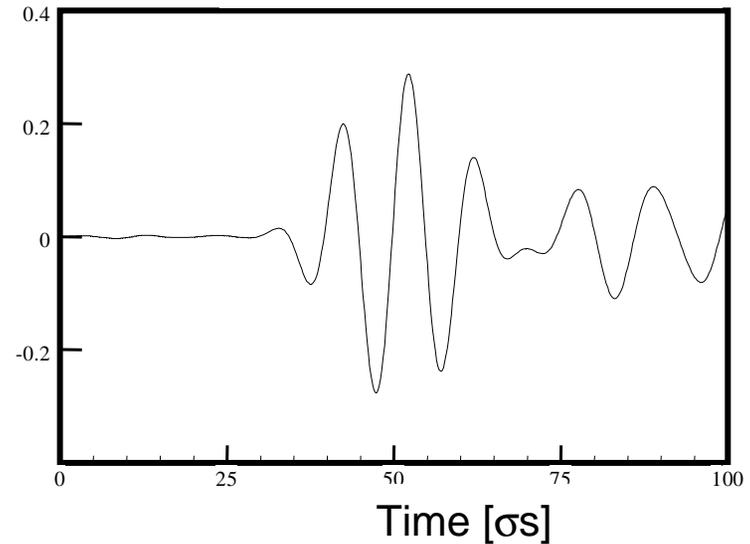
Advanced Fiber Optic and MEMS Ultrasonic Sensors

Fiber Optic Ultrasonic Sensor



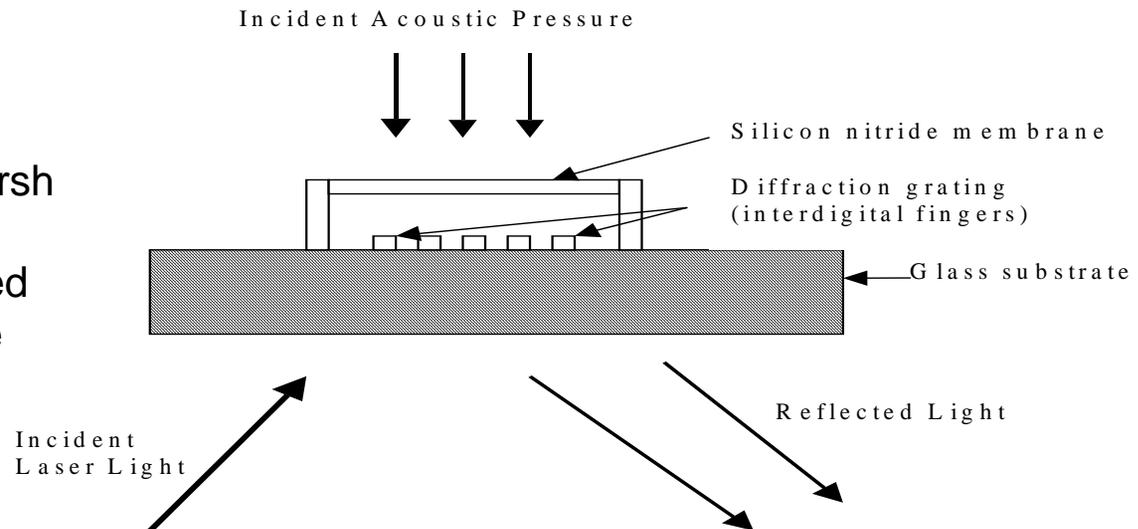
- Responds to in-plane motion
- High sensitivity
- Immune to EM interference

Sensor voltage output

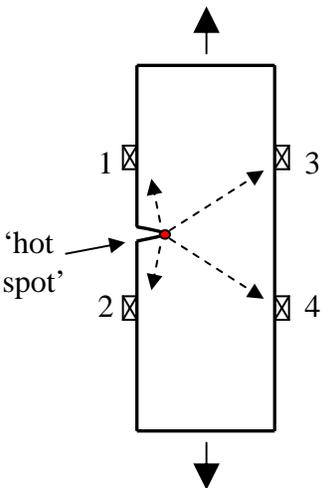


MEMS Ultrasonic Sensor

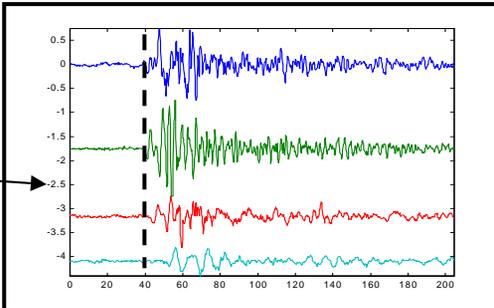
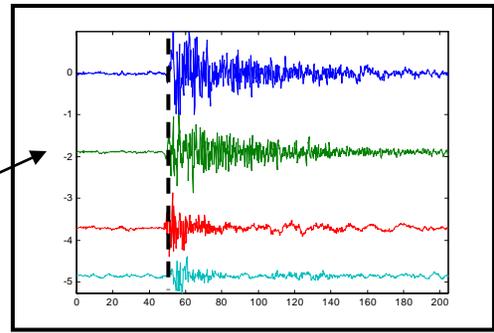
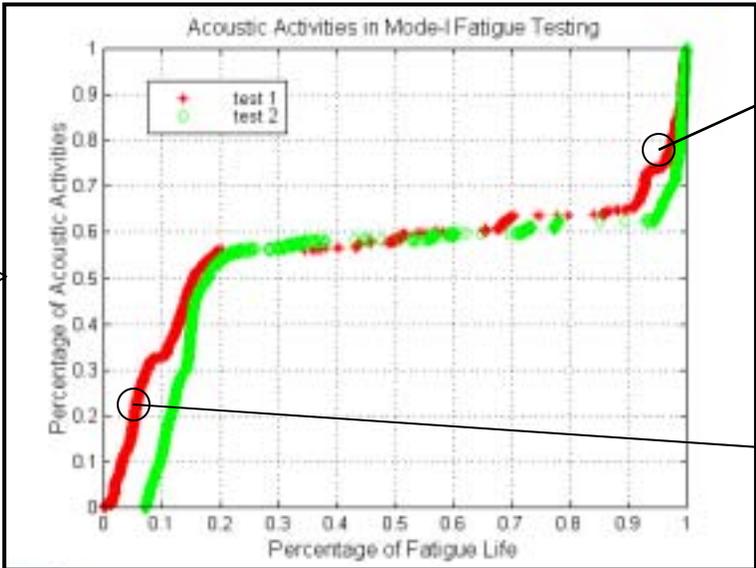
- Non-contact sensor
- Passive monitoring in a harsh environment
- Interdigital fingers deposited on a transparent substrate



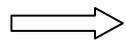
Acoustic Emission During Fatigue Test



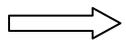
Instrumentation



Fatigue test



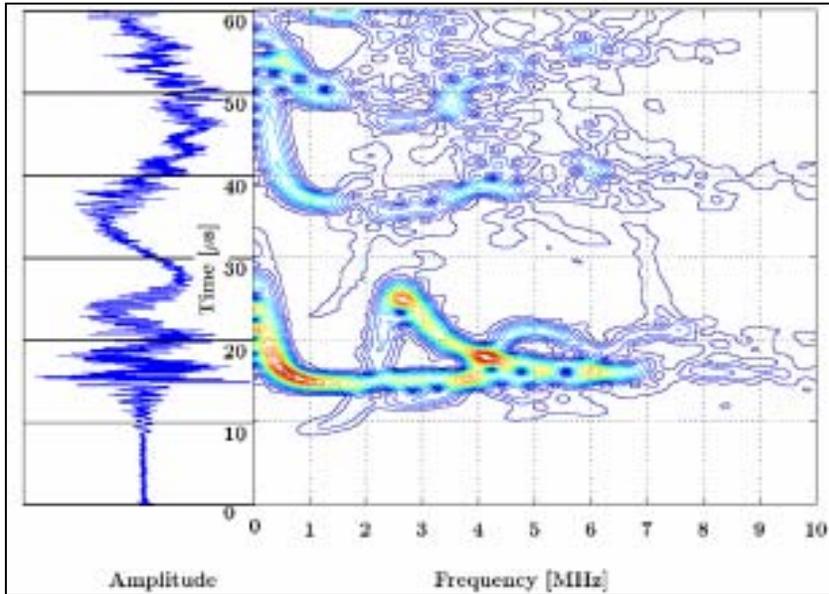
Detected acoustic activities



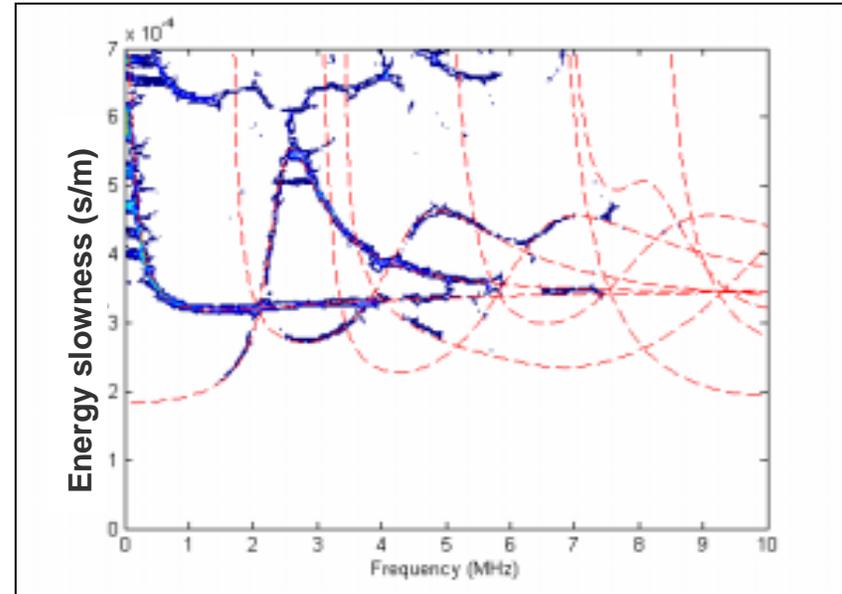
Event signature

Crack Detection Using Guided Waves

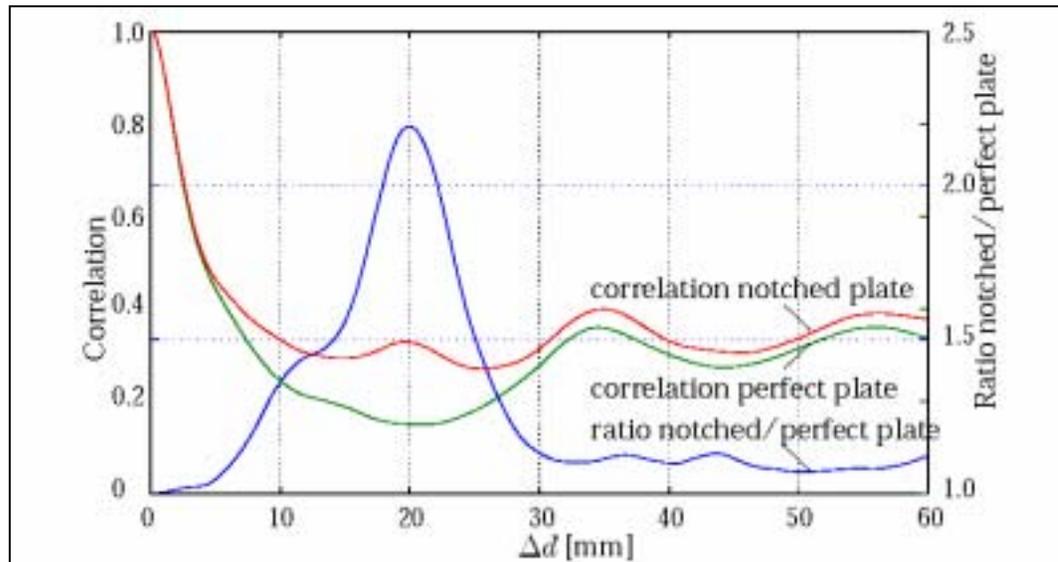
Experimental Time-Frequency Data



Processed Dispersion Curves



Crack Determination and Localization



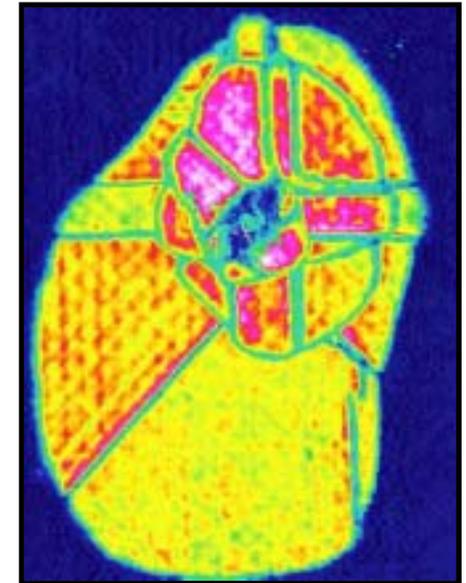
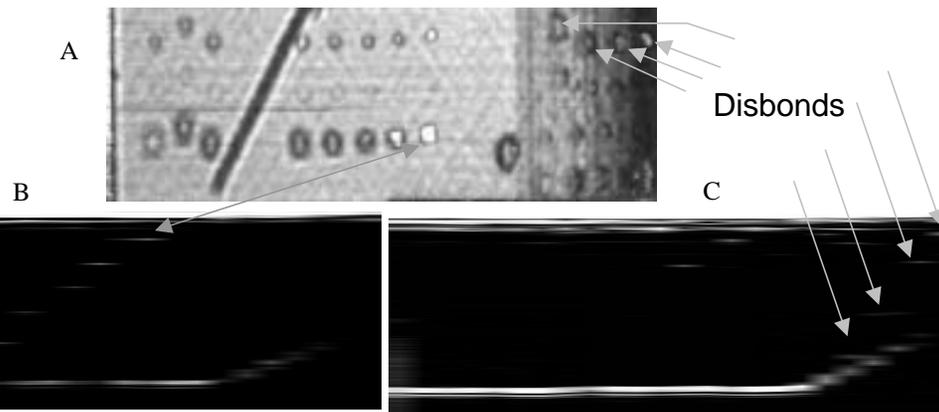
Ultrasonic Imaging for Flaw Detection and Materials Characterization



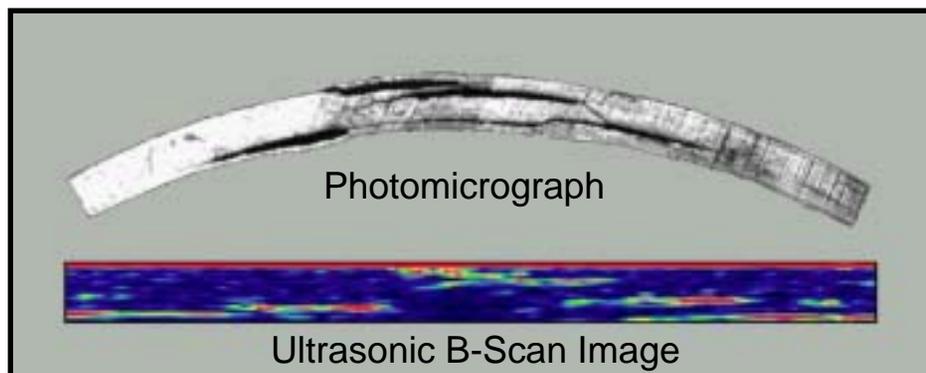
Five Axis Ultrasonic Scanning System



Composite Aerospace Structures



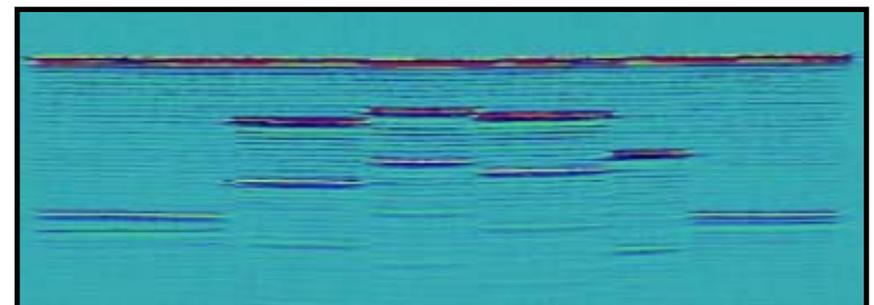
Damage Detection and Characterization



Photomicrograph

Ultrasonic B-Scan Image

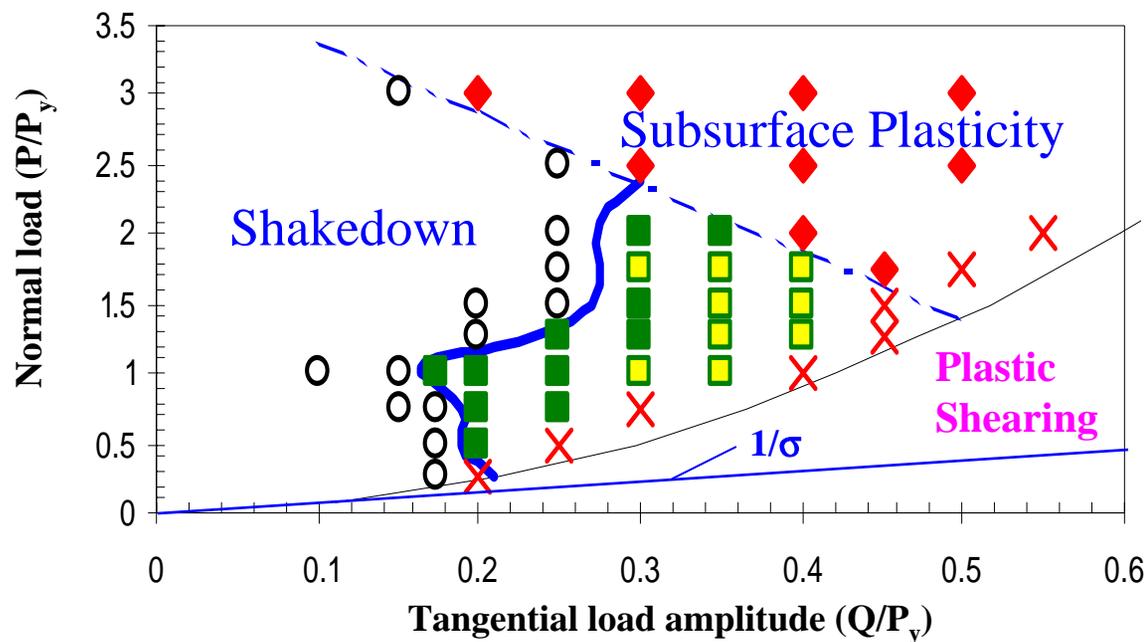
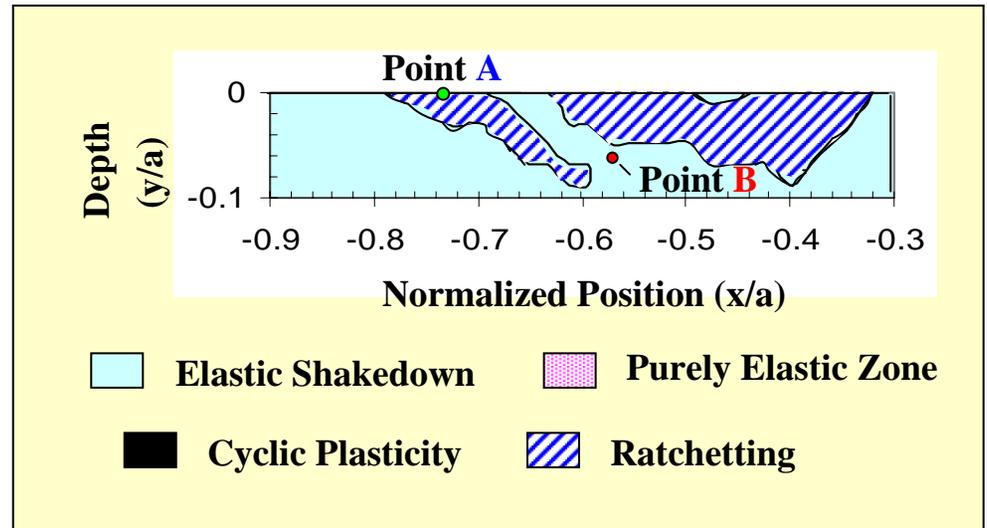
Delaminations Due To Impact Damage



Prediction of Crack Formation From Fretting Analysis

Fretting maps offer means to understand mechanisms of near surface plastic deformation and driving forces for surface wear, evolution of interface friction, and crack formation.

Crystal plasticity analyses show dominance of surface ratchet strain accumulation.



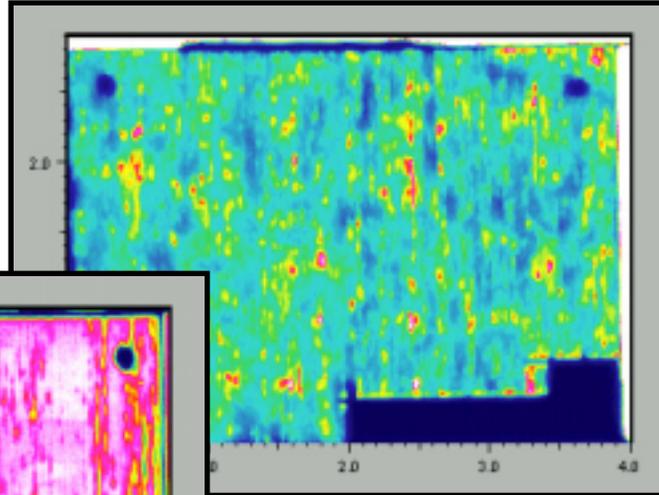
Q_{max} via von Mises Criterion

Example:
Fretting
Map for
Ti-6Al-4V

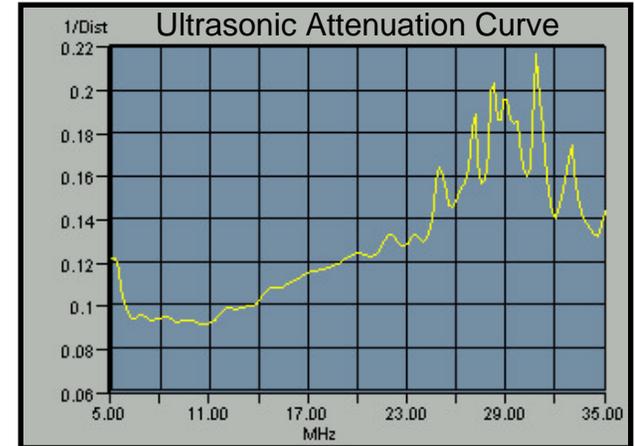
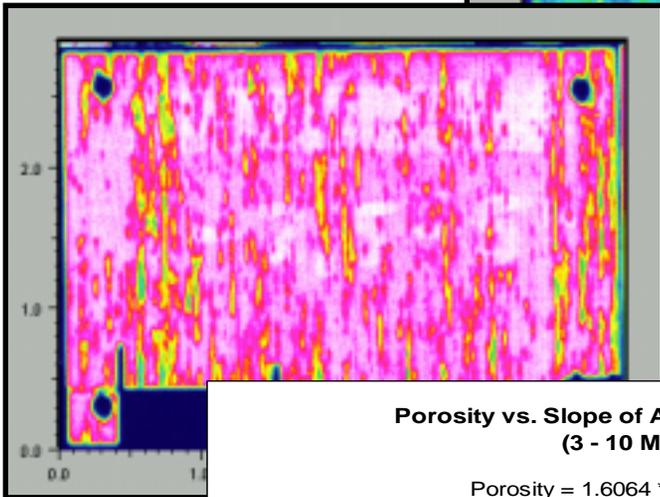
Ultrasonic Materials Characterization

Porosity Determination

Low Porosity

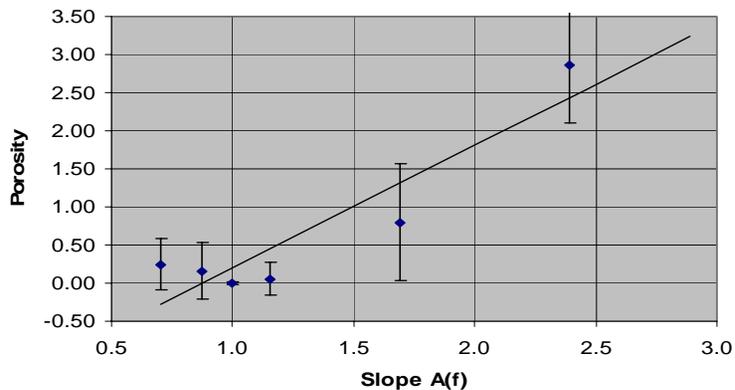


High Porosity

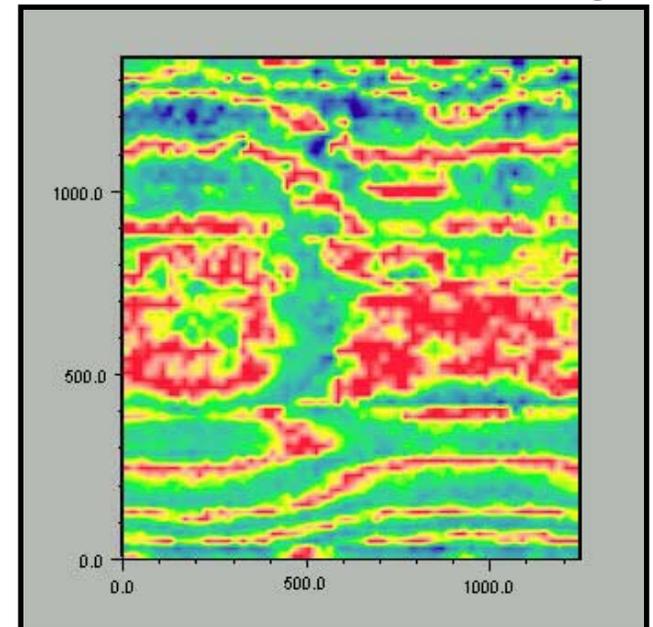


Porosity vs. Slope of Attenuation Curve
(3 - 10 MHz)

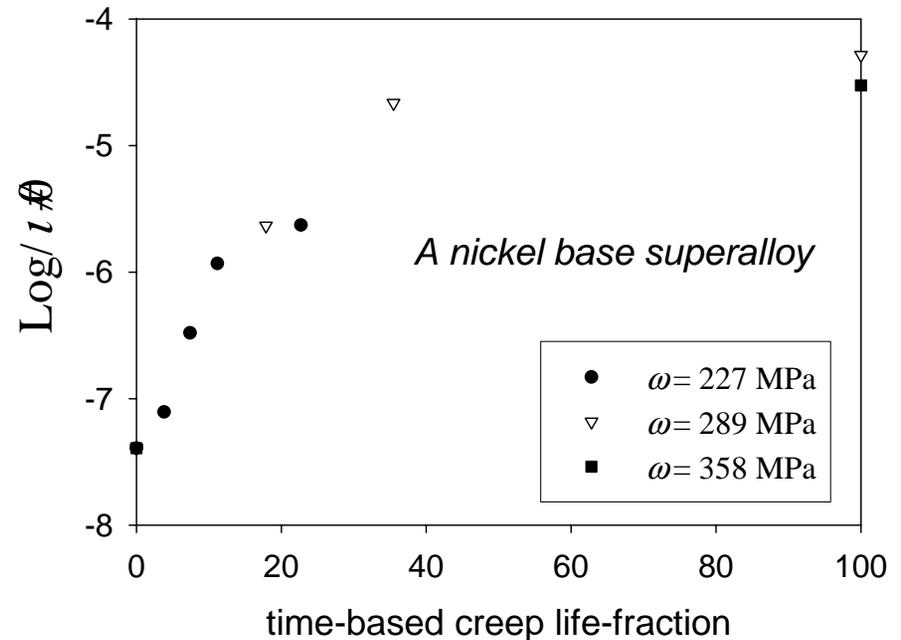
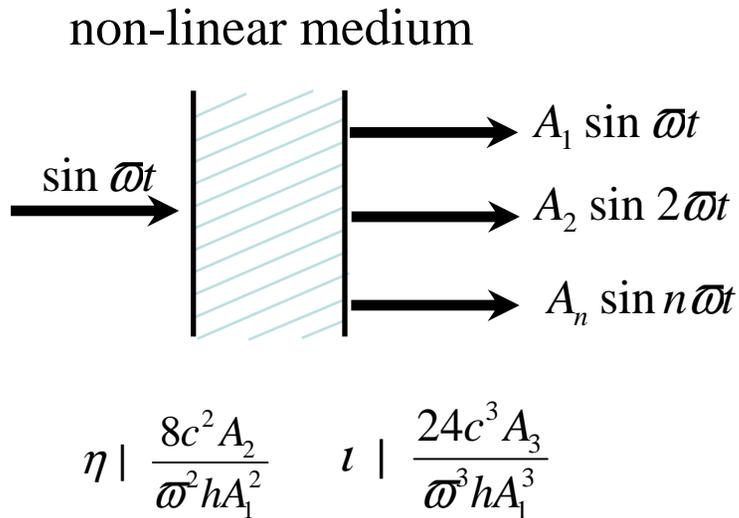
$$\text{Porosity} = 1.6064 * \text{Slope} - 1.4025$$



Residual Stress Mapping



Nondestructive Evaluation of Fatigue and Creep Life in Metallic Materials Using Nonlinear Ultrasonic Techniques

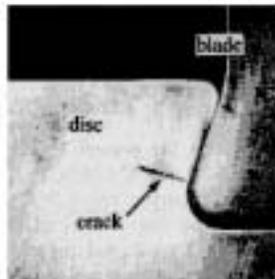


- A_1 -- related to the second order elastic constants (elastic modulus)
- η -- related to material and geometric nonlinearities
- * third order elastic constants (acoustoelasticity)
 - * non-linear stress-strain relationship (plasticity, creep, cracks, etc.)
 - * finite deformation (large amplitude)
 - * dislocations in metals

Fracture Mechanics Approach to Life Prediction

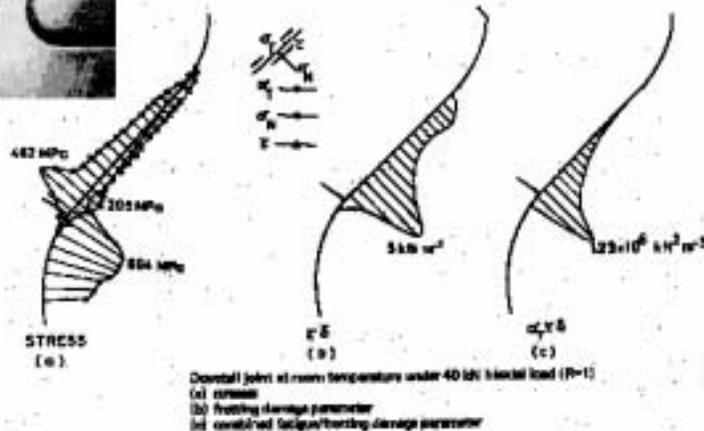
State of the Art

Fretting Fatigue Crack Nucleation

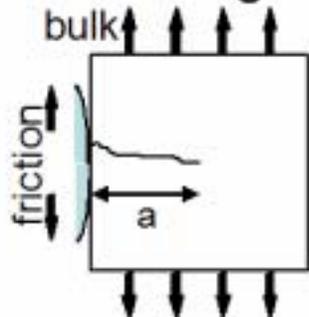


Chen and Ruiz (1986)

- predicts nucleation only



Fretting Fatigue Crack Growth



Fracture Mechanics

$$\frac{da}{dN} = f(\Delta K_{bulk} + \Delta K_{friction} - \Delta K_{red.comb}, K_{mean})$$

- based on continuum description

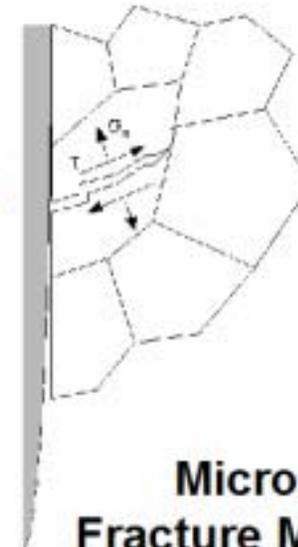
Next Generation

Multiaxial Fatigue Criteria Based on Critical Plane Approaches

- potential to predict both nucleation and direction of early crack growth



LINK

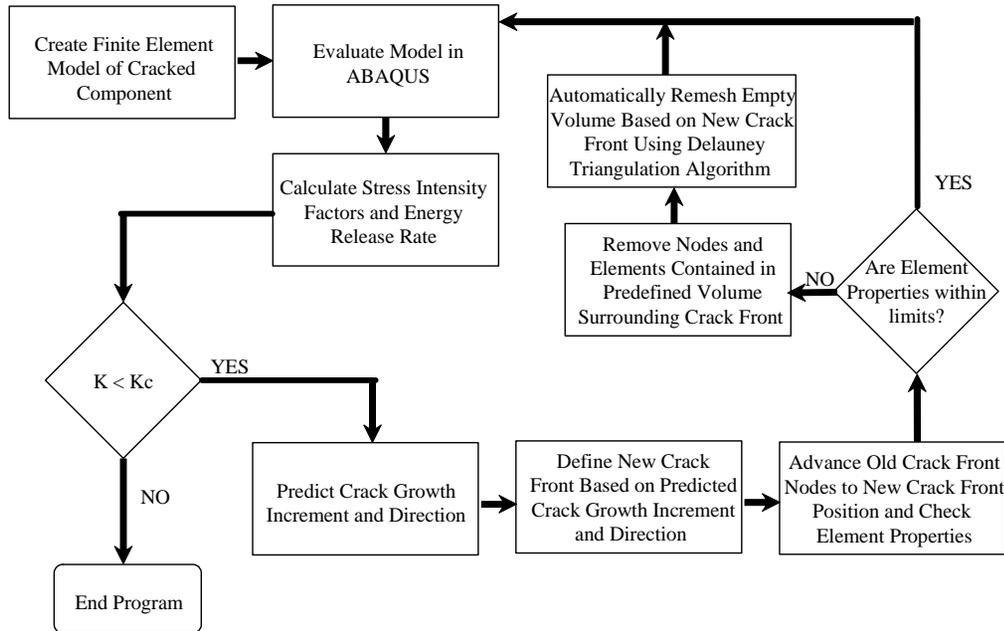


Microstructural Fracture Mechanics

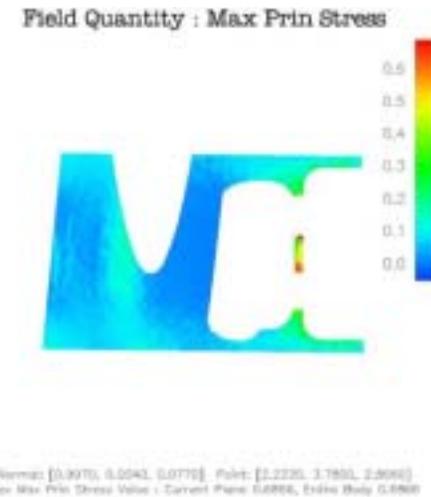
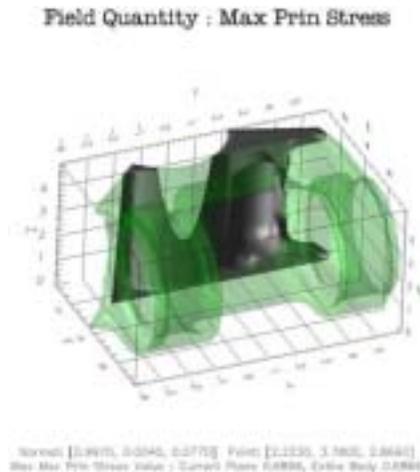
- potential to use length scale appropriate for describing early crack growth where continuum description breakdown

Stress Analysis in Complex 3-D Structure Components

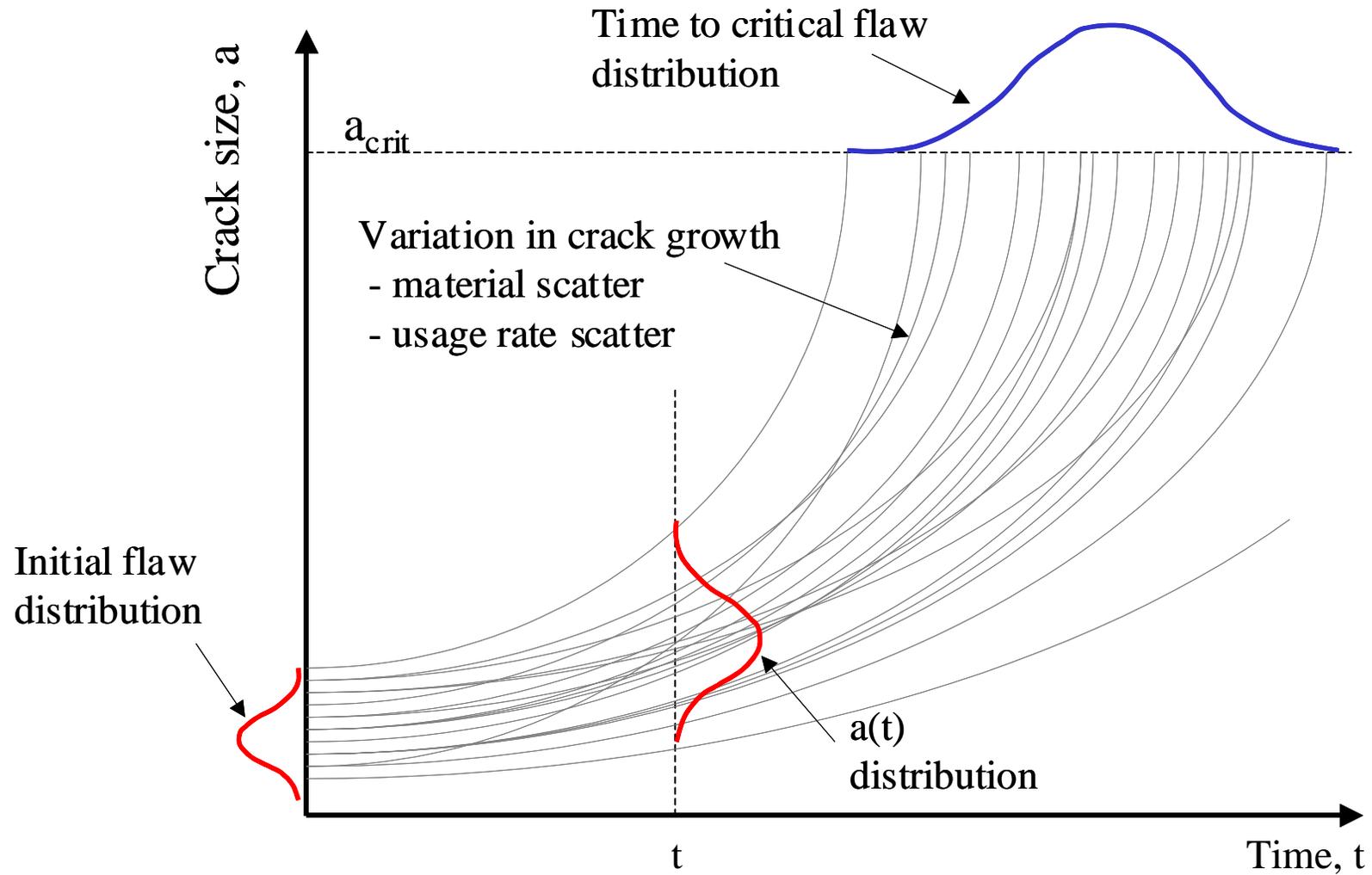
Automatic Crack Growth Flowchart



- Stress analysis identifies “Hot Spots”
- Calculate the "Driving" force (SIF) for crack growth.
- Computational algorithm computes the 3-D crack-front parameters under complex state of stresses.
- Simulation program for calculation and visualization of 3-D crack growth.



Probabilistic Approach to Life Prediction



An Integrated Methodology For Structural Health Prognostics

